Volume 22 May, 1936 *Number 5*

Lubrication

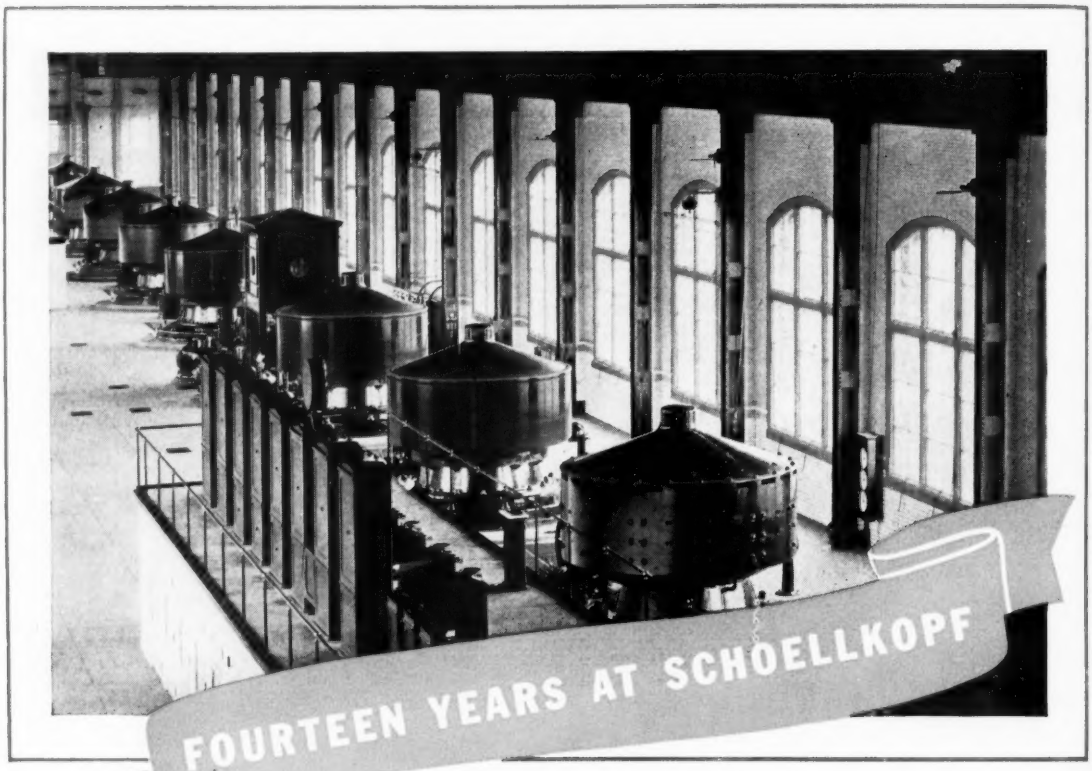
A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Hydraulic Power

Low Temperature
Gear Lubrication

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS



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THE TEXAS COMPANY

LUBRICATION

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Hydraulic Power

PRACTICAL generation of power by hydraulic means through the application of water power upon a rotating wheel is credited to John Smeaton in the middle of the 18th century. At first, although the device was crude and cumbersome, it aroused the enthusiasm of contemporary scientists, and later, more practical originators such as M. Fourneyron, who visualized unlimited possibilities in the harnessing of the elements. Progress in actual development of an economically practical hydraulic turbine, however, was slow. Not until about 1847 did it appear under the sponsorship of James B. Francis, who developed the reaction or pressure type of turbine. In this unit both the pressure and velocity of a stream of water are utilized in doing work. Later the impulse turbine, or Pelton wheel, was perfected. It has proved especially adaptable to high head and small discharges.

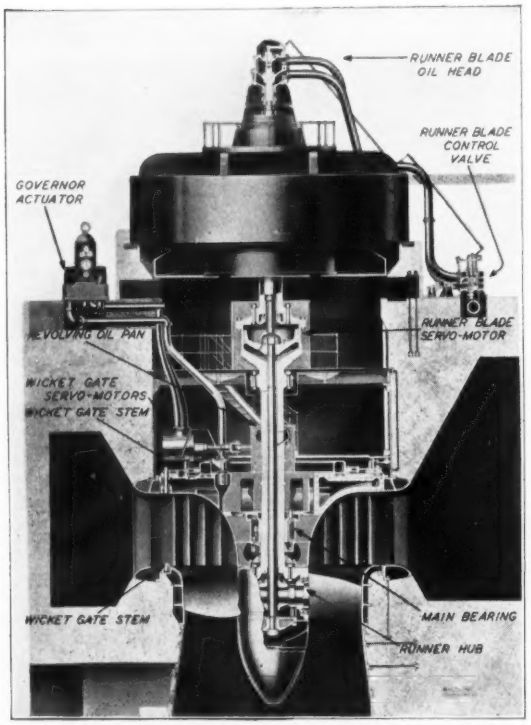
Transportation of constructional materials has played an important part in our 20th century development of the hydraulic turbine. Waterways had to be properly diverted and reservoirs accumulated before water power could be effectively utilized. Dams and canals were even necessary when our forebears used the old mill stream to turn their water wheels which furnished the power for their crude flour mills. Even then the limitations of free-flowing water power were realized. Means of transportation changed all this however; when it was no longer a problem to accumulate huge supplies of cement in remote localities; when the steel industry was able to furnish reinforcing materials of adequate strength; when the power shovel and drag-line were designed to handle hundreds of cubic yards of materials daily, the picture changed. Likewise the landscape. Huge dams were no longer an engineering ideal; they became a reality. Lakes were formed where heretofore the tributaries of mighty rivers flowed. Gorges became their material retaining walls, and the hydraulic turbine took its rightful place as one of the predominating media for generation of electrical power.

The extent to which this development has progressed is clearly shown in POWER for January, 1936.

Once built, however, the problem of transportation is no longer a factor, for the hydraulic turbine requires no great quantity of materials for its operation. No fuel is involved, the volume of lubricants is small, and there is no waste to be disposed of. Above all, however, it must be protected against breakdown. Lubrication will accomplish the desired result.

This matter of breakdown and the necessity for parts replacement requires further discussion. Normally these parts are costly, heavy and cumbersome; frequently they must be specially designed by the turbine builder, hence storage of spare parts is not always economical; and finally, their installation may require importation of a special corps of mechanics for the personnel in an hydraulic

turbine plant is few in number. So, lost time may become a serious and most expensive item, especially where there is not adequate



Courtesy of S. Morgan Smith Co.

Fig. 1—Sectional view through a Smith-Kaplan adjustable blade turbine, showing essential details of the governor mechanism and bearings.

steam generating equipment to carry the emergency load.

In considering lubrication as the predominating factor in continued operation of such machinery, pressure and temperature conditions must be carefully studied; speed is rarely so high as to become a criterion in the maintenance of positive lubrication. The possibilities of oil or grease contamination are also less than in the average steam plant; there is no coal or ash dust and normally the plant is located so remote from manufacturing centers as to assure of an extremely low dust content in the air.

Temperature fluctuation, however, may have a decided effect upon the performance of lubricants. It is especially important to consider the lower range due to the possibility of certain of the mechanisms being exposed to low water temperatures, which may affect the fluidity of lubricating oils or the plasticity of greases. In contrast with the steam turbine, however, abnormally high temperatures can only result from actual metallic friction and impairment of the lubricating film. There is no possibility of external heat being transmitted to the bearings or governor mechanism.

Pressure becomes a factor in planning on the lubrication of thrust bearings. In other words, the dependability of the unit will hinge upon the ability of the lubricant to maintain effective lubrication in the presence of high vertical pressures as developed in the operation of the step or thrust bearing. To aid in the establishing and maintenance of an adequate lubricating film between the thrust elements, unique designs have been developed with marked success. Fortunately, bearing pressure problems are confined to the thrust bearings; normally the guide or steady bearings will not be subjected to loads of any intensity.

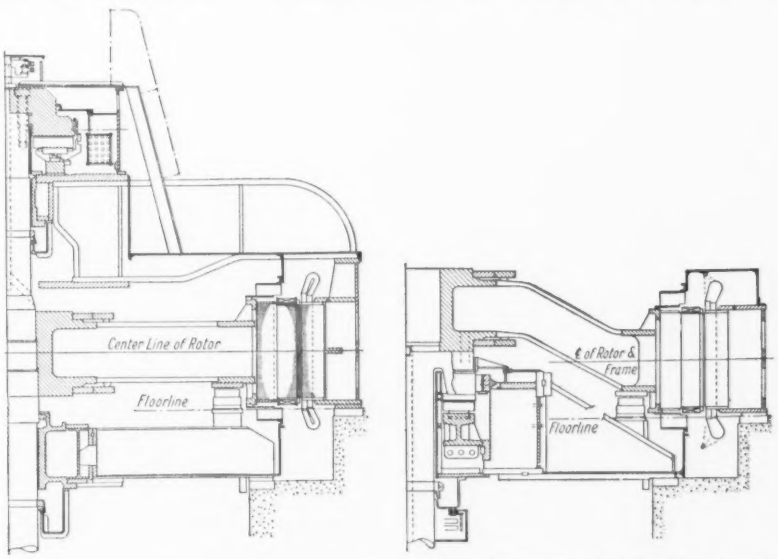
The thrust bearings, however, carry the weight and absorb the load of the entire rotating mechanism. Frequently the bearing pressures will range up to 400 or 500 pounds per square inch, the entire load amounting to well over a million pounds. In a large turbine it is obvious that the thrust bearing must be fully capable of absorbing these pressures; otherwise, if metallic contact occurs, temperatures will rise, wear will also take place to an abnormal degree. There is, therefore, a direct relationship between the operating temperature and the efficiency of the unit. In turn, this relationship applies to the extent to which the thrust is successfully lubricated. In other words, abnormal increase in operating temperatures for the same oil may indicate that excessive power is being consumed in developing actual rotation and overcoming frictional resistance. Hence the necessity for positive oil circulation to bring about a cooling as well as a lubricating effect.

In this way temperature enters the problem. It is solved by use of properly designed cooling coils and circulation of an adequate supply of low temperature cooling water. Actually the coils serve as a heat exchanger, the oil being reduced in temperature continually as it circulates through the oil part of the unit. As in many heat exchangers, however, the outlet temperature of the oil will depend upon the difference between the respective inlet temperatures of the oil and cooling water. Obviously the latter must be as low as possible to accomplish the best results. The load to be assumed by the oil cooler will be controlled to some extent by the direction of rotation.

BEARING DESIGN AND LUBRICATION

Lubrication is accomplished by bath or pressure, according to the type and size of the turbine. Thrust bearing design is also a criterion. Most thrust bearings are bath lubricated. Oil must be maintained at as uniform viscosity as possible; this is accomplished by

external cooling, the use of cooling coils in the bearing housing, or simply by radiation. Guide bearings on the other hand are largely pressure lubricated. Using a grade of oil commensurate with the speed and pressure, best results will normally be attained by operating with the thrust bearing surfaces submerged in oil. This assures of a constant and adequate film of oil between the contact surface of the rotating collar and the companion bearing members. The thickness of this film will depend on the viscosity of the original oil, the pressure between the bearing parts and the surface speed of the rotating collar; bearing design has been improved to cause the oil film to vary automatically in thickness in accordance with the above conditions.

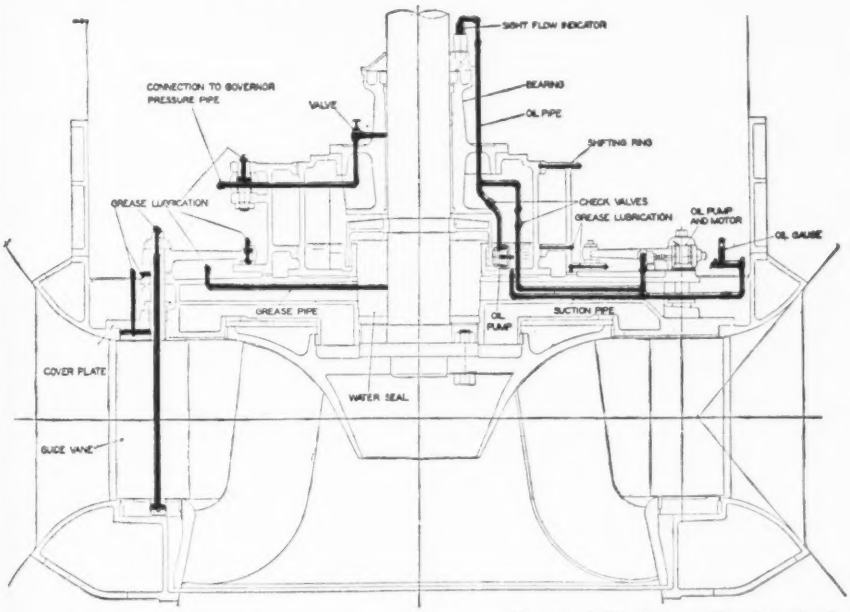


Courtesy of Westinghouse Electric & Manufacturing Co.

Fig. 3—Sectional views showing type of bearings used in Westinghouse water wheel generator units.

Bearings of this type will include the rotating collar type of bearing, such as the Kingsbury, the G. E. Spring type, the Gibbs or the Michell. All have a single rotating collar. Opposed to this latter is a fixed bearing member designed to produce oil films for the surfaces while running. The construction of this bearing member will depend upon the type of bearing.

In the Kingsbury bearing a plain collar forms one bearing member, the other being formed by pivotted shoes or segments. These latter are free to tilt both radially and tangentially by virtue of their manner of support. They will be completely covered during operation by an oil film which will automatically change its shape and thickness to conform to the load imposed, the speed of operation and the relative fluidity or viscosity of the oil.



Courtesy of Allis-Chalmers Manufacturing Co.

Fig. 2—Details of an Allis-Chalmers hydraulic turbine, showing points to be lubricated with oil and grease. Note also the guide vane lever bearings, the shifting ring bearing surfaces and the grease packed water seal.

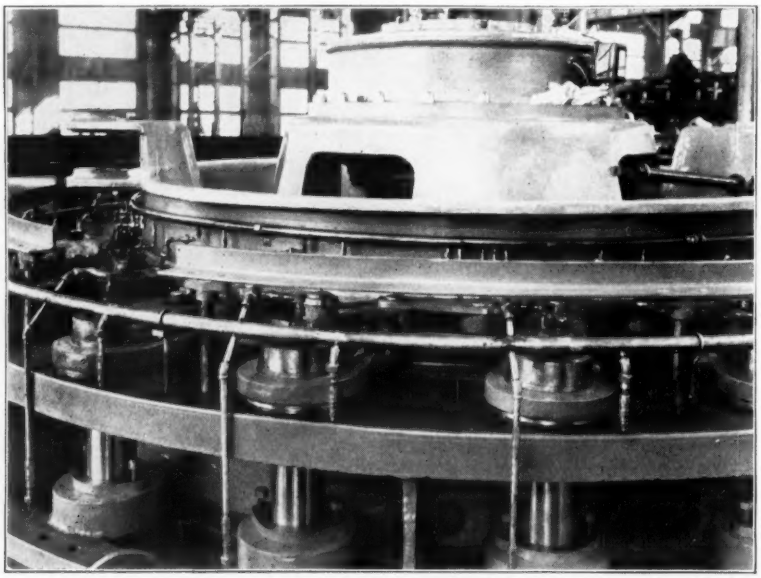
The Michell type of bearing is very much akin to the Kingsbury in regard to principles of operation. The G. E. Spring type bearing, in turn, involves a collar or runner which rests on short helical springs, maintained in position by dowel pins on the base casting. The Gibbs bearing works on the fixed wedge principle.

The modern thrust bearing is designed for

uniform distribution of load, regardless of location. In the average hydraulic plant, vertical location will be more prevalent. The operating efficiency, as already mentioned, will hinge not only upon the bearing design but also upon the ability of the oil to maintain a lubricating film of adequate thickness. In view of the fact that the thickness of the oil film will be in part contingent upon the viscosity at the operating temperature, as well as the total load, familiarity with this property is always helpful. On the other hand, film thickness is not the same in all bearings. In bearings of extreme film thickness, power losses can be reduced by running bearings hotter.

In general, bearings of considerable size carrying heavy loads at low speeds will present more of a lubrication problem than the high speed bearing of lower duty. As Kingsbury states—"For low speeds and heavy loads a thick oil must be used, while for high speeds and moderate loads a thin oil is preferable. The reason for this practice lies in the thickness of the oil film. It must be great enough to separate the bearing faces. It requires a heavy oil to do this at low speed and high unit pressure, whereas a light oil will bring about an adequate separation at high speed and moderate unit pressure." *

* Kingsbury Thrust Bearings, Catalog C, Page 10.



Courtesy of Baldwin-Southwark Corporation—I. P. Morris Division

Fig. 4—Showing the piping essential to the lubricating system of an I. P. Morris hydro-electric turbine.

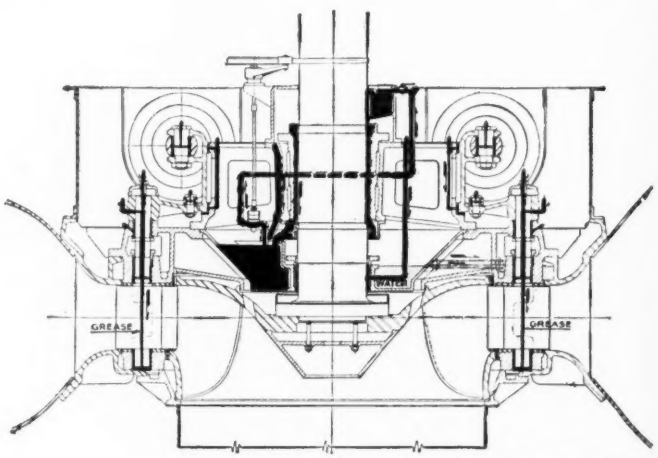
In low speed bearings using heavier oils, higher pressures can be applied; this holds especially true for larger bearings.

Guide and Steady Bearings

The number of guide bearings required in an hydraulic turbine will depend upon the speed of rotation and length of the shaft. Usually there will be three of such bearings; one located at the top of the generator, one directly below the rotor and one on the top of the turbine wheel.

Babbitt, lignum vitae or rubber can be used as bearing material. Very often the top bearings will be babbitted, lignum vitae being used above the crown plate of the turbine wheel, but rarely adjacent to the generator. Lignum vitae and rubber are advantageous in that they are lubricated by means of water, although it is perfectly practicable to design lignum vitae bearings for grease lubrication. Where this is to be carried out, pressure application of the lubricant to the bearing is advisable. Lignum vitae is not adaptable to heavy loads.

It is usual, however, to lubricate babbitted guide or steady bearings with oil by either gravity or mechanical pressure circulation to insure the maintenance of a suitable lubricating film within the clearance spaces.



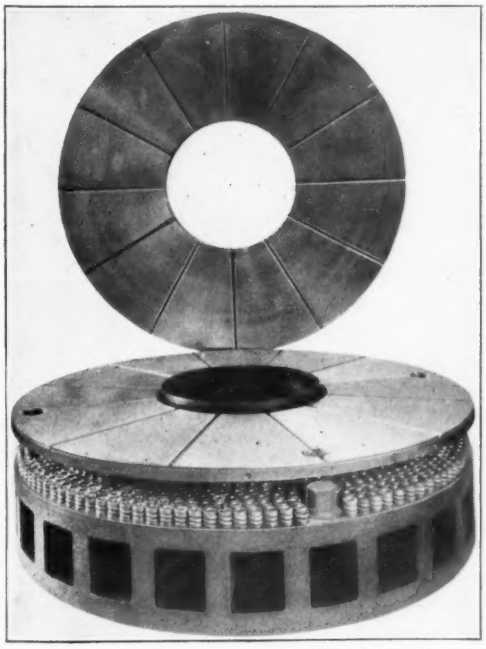
Courtesy of Newport News Shipbuilding & Dry Dock Co.

Fig. 5—Details of the base of a Newport News hydraulic turbine installation, with oil and grease connections outlined in heavy black. Path of the oil flow adjacent to the rotor shaft is plainly indicated.

By reason of this practice, such bearings are normally designed with the lubricating systems entirely enclosed; i.e., built so that there is but a minimum possibility of entry of abrasive dust, or moisture.

The oil pump as an adjunct to pressure lubrication is sometimes more satisfactory than gravity feed, due to more complete concentration of the lubricating piping and the ease with which the oil supply can be located adjacent to the bearings. In such installations the oil pump is installed within the oil reservoir, with suitable lines and sight feed controls to the bearings, and return leads from each bearing back to the reservoir.

Any such system can, of course, be amplified by means of a filter or oil purifier. In general, such devices operate on the continuous by-pass method, whereby a certain amount of oil is constantly removed from the total volume in circulation and passed through the purifying device prior to return to service. It is also practicable to combine certain types of thrust bearings with the upper guide bearing, which is located adjacent to the generator.



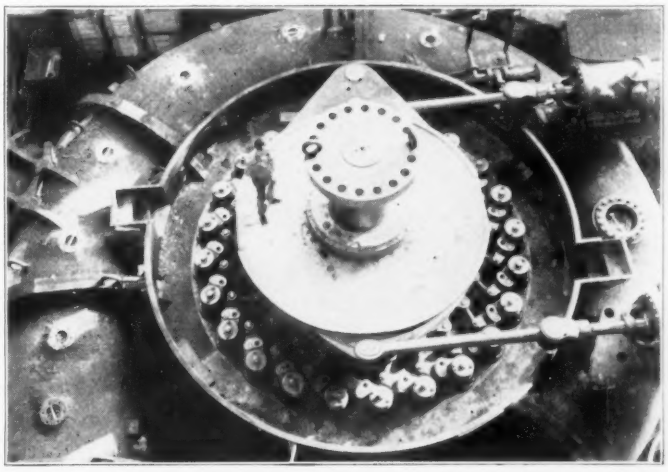
Courtesy of General Electric Co.

Fig. 6—Showing the General Electric type of thrust bearing as used on hydro-electric generators. The distinctive feature of this design is the spring support of the stationary babbitted plate.

SYSTEMS OF LUBRICATION

Automatic lubrication predominates in hydraulic turbine design, in accordance with the location and accessibility of the parts to be lubricated.

For example, guide and thrust bearings are normally lubricated by some form of automatic circulating oiling system, although it is perfectly practicable to run certain types of thrust bearings in a bath of oil provided there is ample capacity and adequate means for cooling the oil in the bath. Guide bearings, however, are largely pressure lubricated by means of a gear pump, located in the oil pan or reservoir, either adjacent to or below the bearing to be served. Best practice is to install the lubricating system right at the unit with provision for starting prior to starting of the unit. Sight feed indicators are advisable in the distributing pipes to show the rate of oil flow.

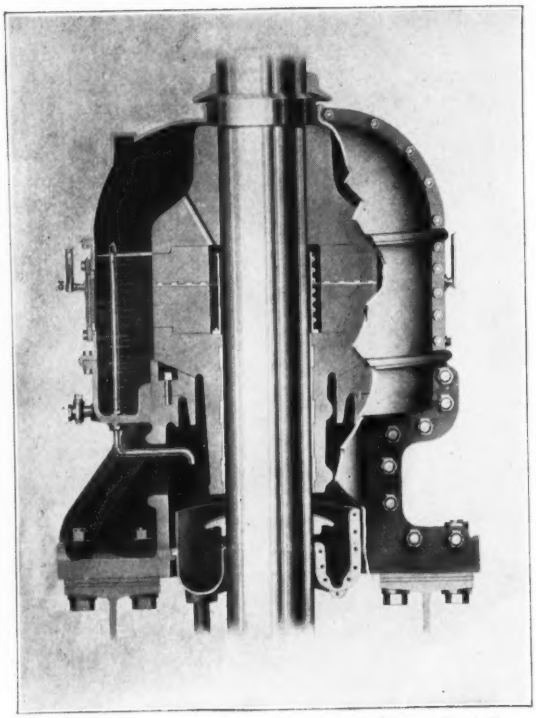


Courtesy of Allis-Chalmers Manufacturing Co.

Fig. 7—Showing the gate operating mechanism of an Allis-Chalmers hydro-electric turbine. All moving parts have means for grease lubrication through pressure gun fittings.

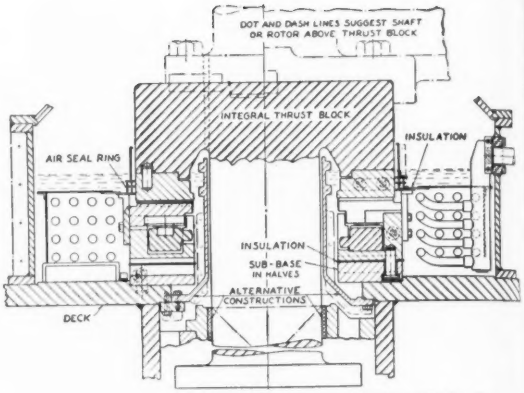
When only the guide bearings are to be served by such a system, the oil after passing through these bearings is returned to the oil pan or reservoir for cooling, when necessary, and recirculation. Where the same system of lubrication is to serve both guide and thrust bearings, however, the oil is oftentimes first carried to the upper guide bearing and thrust bearing, and from thence to the lower guide bearing prior to return to the oil tank. On the other hand, it is practicable to run an individual line to this latter bearing, leading off the main distributing pipe.

Centralized pressure lubricating systems can also be adapted to large installations involving more than one generating unit. The principle involved in a centralized pressure system will be very much the same as that explained above, with the exception that the oil pumps are independently driven and have no connection to any of the shafting. In such systems it is



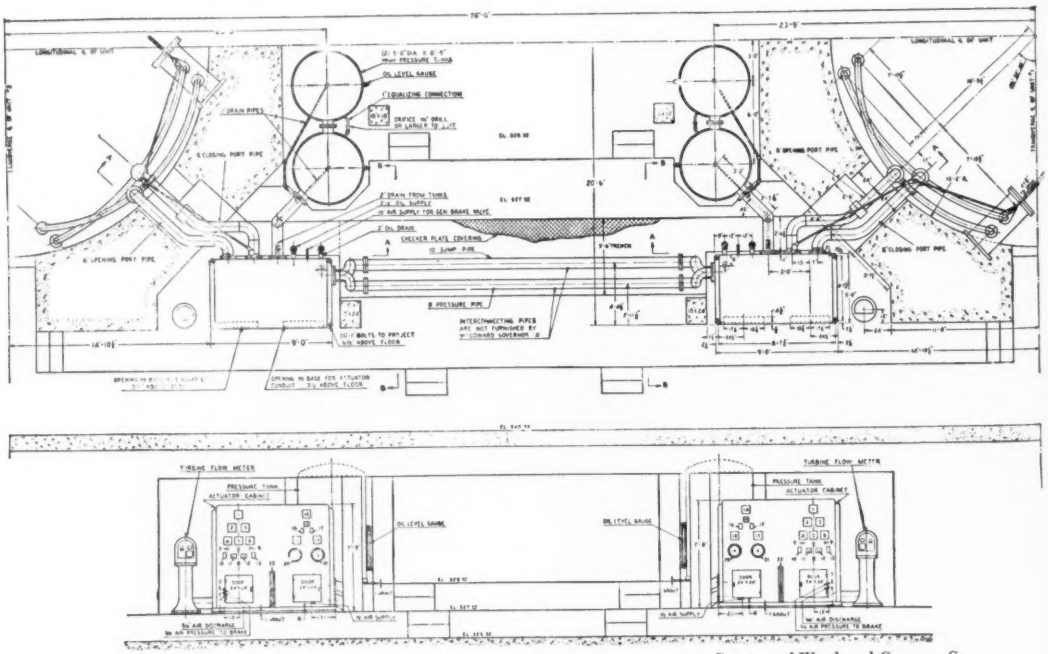
Courtesy of S. Morgan Smith Co.

Fig. A—Phantom view of a Gibbs oil bath type thrust bearing. A feature of this bearing is the positive degree of lubrication which is developed regardless of speed.



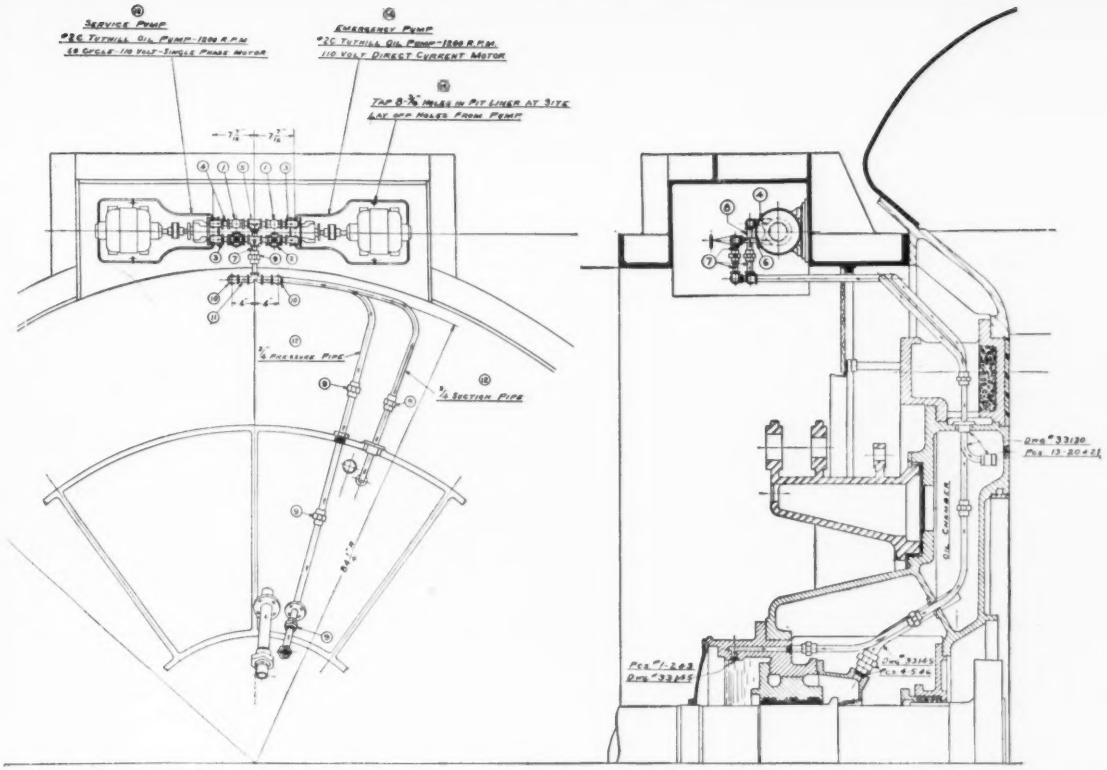
Courtesy of Kingsbury Machine Works, Inc.

Fig. B—A Kingsbury thrust bearing designed for high speed hydro-electric service. Alternative construction allows the split oil seal ring to be dismounted from top or bottom, or from the bottom only.



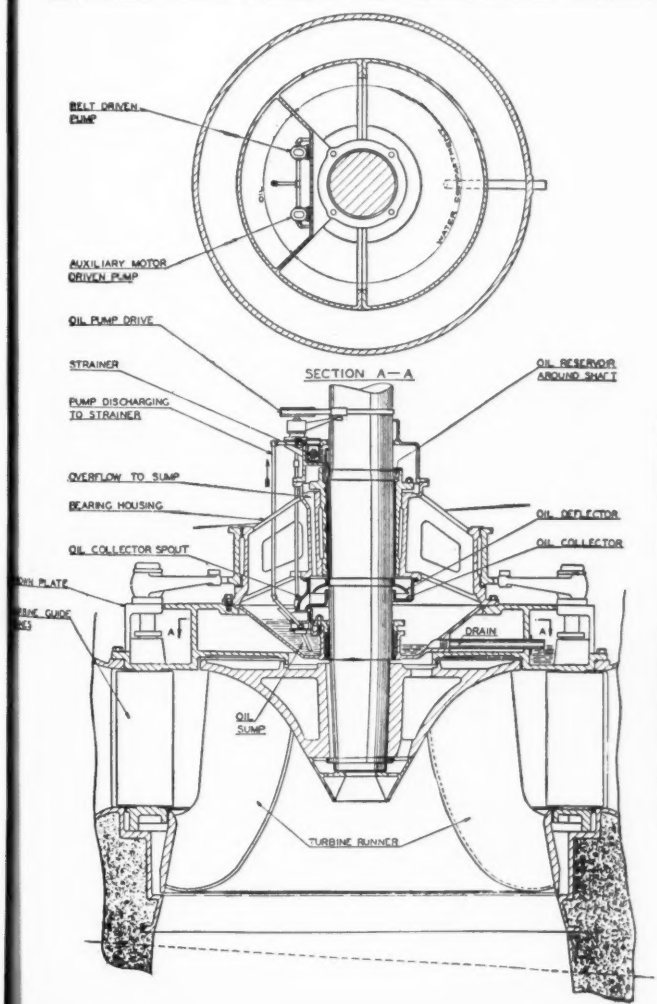
Courtesy of Woodward Governor Co.

Fig. C—Typical installation of a Woodward "Twin System" governing installation. Note in particular that valves have been provided to permit isolation of the oil pump pressure tank or relay, and enable operation of the actuator alone or in parallel. Each actuator sump is adequate to hold all the oil in the governing system, and is provided with a manually controlled valve which permits isolation from the sump tank of the companion unit.



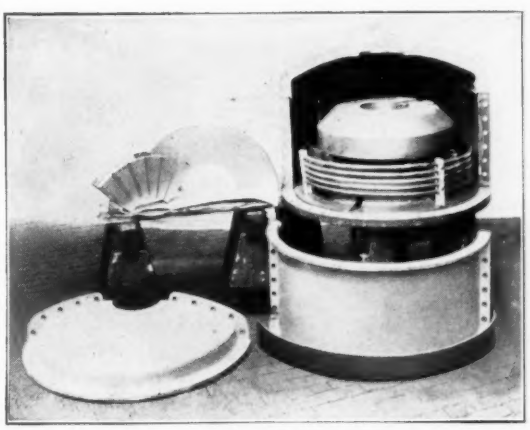
Courtesy of Baldwin-Southwark Corp.,—I. P. Morris Division

Fig. D—Showing the arrangement of pumps and oil piping to main bearing of an I. P. Morris hydraulic turbine. Direction of oil flow is shown by arrows.



Courtesy of Newport News Shipbuilding & Dry Dock Co.

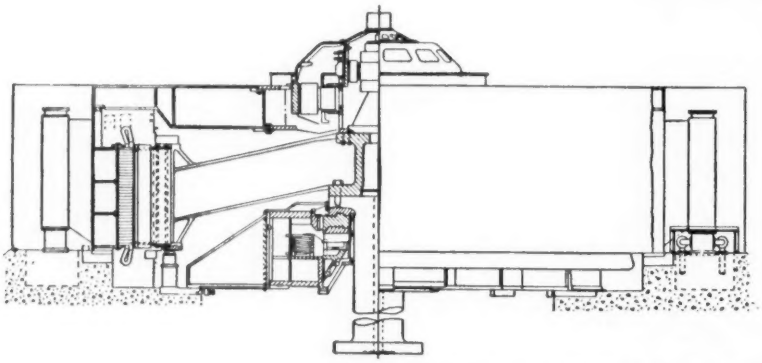
Fig. E—To the left is shown the lubricating system of a vertical Francis turbine. The oil supply is carried in an oil sump below the bearing. It is pumped upward through a strainer and flows therefrom through an auxiliary and secondary oil reservoir above and through the bearing. There is an over-flow to carry excess oil back to the sump.



Courtesy of Allis-Chalmers Manufacturing Co.

Fig. F—Showing an Allis-Chalmers oil bath type thrust bearing.

customary to use motor driven pumps equipped with automatic controls. An accumulator or pressure tank is provided for each generator. This will eliminate the possibility of pulsation or inertia within the supply lines to the various bearings. In addition, bearings must be protected against dirt or scale generated outside of themselves, hence the necessity for suitable filtration media.



Courtesy of Westinghouse Electric & Manufacturing Co.

Fig. 8—Typical view of a Westinghouse vertical umbrella type water wheel generator, showing the combination thrust and guide bearing used in slow speed machines.

Grease Lubrication

Grease lubrication in hydraulic turbine service is a matter of selecting products capable of functioning under moisture conditions and oftentimes low temperatures. In this regard we are concerned with the runner or wheel housings, and the wicket gate bearings. Wherever practicable, provision is made to supply these parts with grease under a certain amount of pressure.

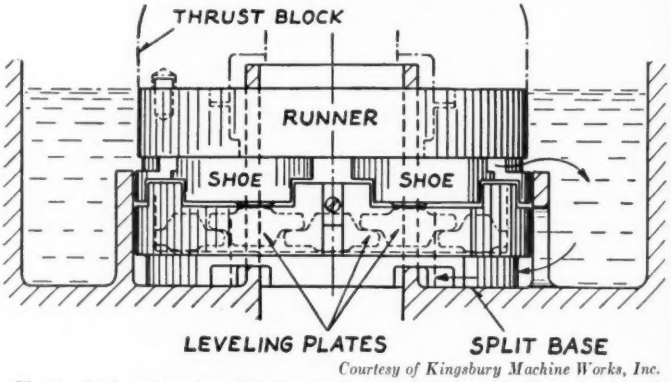
Normally an insoluble grease should be used. By this is meant a product which can be used in the presence of water without its soap content passing into solution to impair the intended homogeneity and consistency of the grease.

If relubrication is carried out at regular intervals, according to the degree of motion existing in the parts to be lubricated and the ability of the grease to maintain its position within the bearings, a positive film of lubricant can be assured within the clearance space.

The extent to which positive lubrication can be maintained on such parts will depend upon the degree of submergence. This is one of the points affecting the use of vertical turbines with more than one runner. Where such construction is involved it is essential to submerge the gate mechanism almost entirely, with the result that the attendant bearings may not be dependably lubricated.

Furthermore, there are more complications involved in designing the essential parts. With the single runner type of turbine, however, the gate mechanism can be built exposed, so that there will be less possibility of any parts being in contact with water except the gates. This will enable positive lubrication of all pin connections and bearings, provided suitable means are installed for this purpose.

Gate mechanisms likewise present potential lubrication problems. As normally constructed, they involve a considerable number of moving parts which are subject to wear and deterioration. This latter must be especially guarded against, for it will be hastened by the corrosive effects of water and damp air along with the abrasive action of grit. Proper housing with provision for adequate lubrication will prevent both wear and deterioration of the mechanical parts; in addition, the action of the governor will be facilitated. Obviously the same type of water-resistant grease as required for the turbine runners should be used on the gate mechanisms. Sometimes, however, a lighter grade will function best, or at least lend itself to more ready application by pressure gun. This will be especially true in cold weather.



Courtesy of Kingsbury Machine Works, Inc.

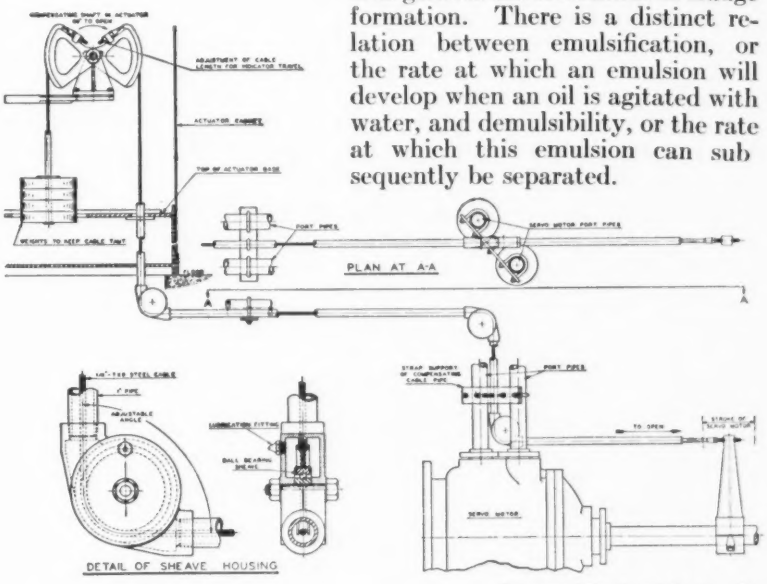
Fig. 9—Section through a Kingsbury 6-shoe vertical thrust bearing, showing oil circulation and main features of the mounting. In this bearing the load is automatically equally distributed among the shoes by means of the leveling plates.

LUBRICATING OIL CHARACTERISTICS

In selecting oils for hydroelectric turbine bearing lubrication and governor operation one must consider their resistance to emulsification, their relative fluidity at comparatively

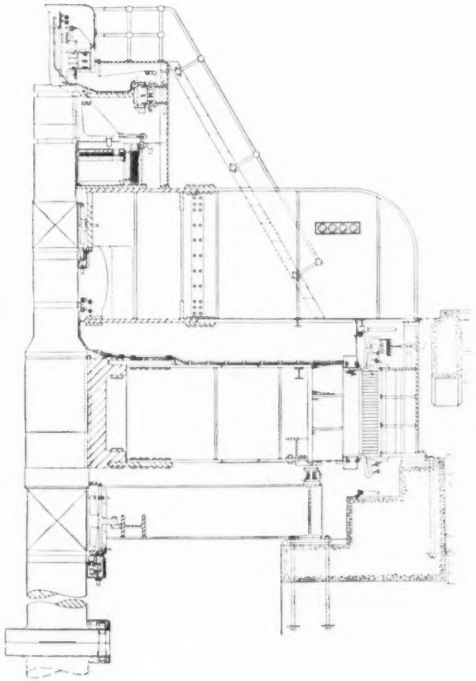
low temperatures and their ability to withstand the prevailing pressures. Normally the possibility of oil breakdown due to oxidation will not be as likely as in steam plant operations, for operating temperatures will be lower although those other oxidizing assistants, such as air, water and metals, are still present.

Resistance to emulsification is therefore important, not only in the interest of reducing the formation of oxidized residues, but also the prevention of emulsified matter which might seriously interfere with free circulation of the oil through the lubricating system. This property is measured by the demulsibility or relative rate at which an oil will separate from water; it is also termed resistance to emulsification, according to the method of determination. These factors are of vital importance where turbine oils are concerned, since wherever an emulsion may prevail to any extent impaired lubrication may result. In fact, emulsification is in general the forerunner of sludge formation. There is a distinct relation between emulsification, or the rate at which an emulsion will develop when an oil is agitated with water, and demulsibility, or the rate at which this emulsion can subsequently be separated.



Courtesy of Woodward Governor Co.

Fig. 11—Showing a typical restoring connection arrangement for a Woodward Governor. Note relative location of Servomotor port pipes and means for lubricating sheave housing.



Courtesy of General Electric Co.

Fig. 10—Cross section view of a 77,500 K.V.A., 81.8 R.P.M., vertical water wheel generator. The thrust bearing which carries the weight of the rotating elements is located in an oil bath near the top of the machine. Circulation of oil to the two guide bearings is maintained by a small oil pump located in the oil pan below the lower guide bearing, driven by gears from the generator shaft.

Wherever water may gain entry into the lubricating system the possibility of emulsification and the subsequent demulsibility must be given the most careful attention, not only when making initial selection and purchase of a lubricating oil but also in its subsequent storage, handling and application.

The rate at which an oil will clarify itself of emulsified matter, and the completeness of this reaction will depend upon the base or nature of the stock and the manner in which it has been refined. More specifically, this means the extent to which the oil is a residual product or a pure distillate, the care used in fractionating or segregation of distillates of a narrow range of viscosity, the extent to which these distillates designed for turbine service are subsequently filtered and the type of solvent used in extraction of unstable compounds.

Relative Fluidity

This property in a lubricating oil intended for service in the thrust or guide bearings of a hydro-electric turbine or the governor mechanism will involve both the viscosity and pour test. These properties are important in view of the fact that in such service the oil may often have to function at comparatively low temperatures. Under these conditions the natural tendency of petroleum products is to become heavier and less fluid. With some, of course, according to the degree of refinement

or the nature of the crude oil from which the lubricant has been obtained, this will be more pronounced than with others. Normally a straight distilled oil of naphthene base can be most economically refined to adequate fluidity, at comparatively low temperatures, or in other words, low pour test. One should consider, therefore, the operating temperatures which may prevail in the bearings when selecting a lubricating oil for such service.

On the other hand, viscosity is commonly measured with respect to a more constant and considerably higher temperature; i.e., 100 degrees, 130 degrees or 210 degrees Fahr., according to the nature of the oil. A lubricant for hydraulic turbine service is normally purchased on a viscosity at 100 degrees Fahr., basis, or, in other words, the number of seconds required at this temperature for 60 cubic centimeters of the oil under consideration to flow through the orifice of the Saybolt Universal Viscosimeter, which is now the standard instrument used in the United States for lighter bodied oils. Usually an oil which will take from 200 to 500 seconds at 100 degrees Fahr. to pass through the above mentioned viscosimeter will be adaptable to the bearing and governor mechanisms of the average unit.

From a pour test point of view, or in other words, the temperature at which the oil will practically cease to flow, it is well to remember that this temperature should be preferably in the neighborhood of zero degrees Fahr. Under actual operation, of course, the oil in circulation will function at a higher temperature. One must consider, however, the ease of starting and the extent to which the oil will flow to the pumping mechanism when cold. As in the case of the automotive engine, instantaneous flow is essential regardless of the starting temperature. If the oil does not lend itself to this, obviously abnormal wear of certain of the parts may result.

In this regard it is well to remember that the effect of cold upon lubricating oils is not the same as upon simple fluids such as water, alcohol, glycerine, benzene, etc. The latter have fixed and accurately ascertainable freezing points at which a complete change from the liquid to the solid state takes place, but lubricating oils which are mixtures of hydrocarbons of various melting points or freezing points behave like solutions, and frequently deposit some portion of their constituents before the whole mixture solidifies.

Interesting phenomena which can only be explained by changes in the physical structure are observed in the pour test of many lubricating oils. If, for example, we take the pour test of an oil without previous heating and then take the pour test of the same oil after heating to 120 degrees Fahr., after it has cooled to the same temperature as the first, the oil which is heated solidifies at a considerably higher temperature, and the influence from preheating seems to be effective for a considerable time, at least for 24 hours. Heating to temperatures below 90 degrees Fahr. apparently has no influence.

Another factor which has an effect on the test is stirring the oil while cooling to determine the pour test. In case an oil is stirred it solidifies at a lower temperature than when held stationary. This may be explained on the assumption that the movement of the oil destroys the formation of the fine network of microscopic particles which are separating out.

Low Temperature Gear Lubrication

The lubrication problem of a new machine is frequently depreciated and occasionally ignored by its designer. Since lubricants are no more universally adaptable than other engineering materials, the selection of a suitable one in such cases may consequently be difficult. In addition to the conditions which are arbitrarily fixed by the original design of the unit, the lubricating engineer must also consider the probable use and abuse to which the machine will be subjected under service conditions.

In order to illustrate some of the most important questions which must be answered before selecting a gear lubricant, the following table has been prepared. The answers to the test questions in this table are applicable only to the most common designs, but each "No" represents a difficulty which the lubricating engineer must consider.

Open or uncovered gearing is usually confined to massive slow speed machinery and is commonly of the spur type. Since tooth loadings are purposely kept low by the designers, and since running clearances are large, satisfactory lubrication can be obtained by painting the gear teeth regularly with a tenacious and highly adherent lubricant. Shaft bearings in such service are usually separately lubricated by means of oil cups or pressure grease fittings. Even though such machines may be subject to wide temperature changes, and although ice or frozen mud will occasionally get into the gear teeth, the lubrication problem is relatively simple.

When, however, the operating speeds are increased, a greater refinement of design becomes necessary; the spur type of gear is discarded in favor of the helical or herringbone type, and running clearances are decreased to reduce noise. Lubrication is usually accomplished by submerging a portion of the gearing in a bath of lubricant, agitation being depended upon to supply lubricant to the remainder of the mechanism. Some designs of automobile differential gears are so designed that the ring gear also serves as the impeller of a centrifugal pump.

Gearing Design and Operating Conditions	Bull Gear On Punch Press	Traversing Gear On Excavator	Indus. Electric Motor Reduction Gear	Differential Gear On Automobile	Operating Mechanism Domestic Washing Machine
Large Operating Clearances?	Yes	Yes	No	No	No
Easily Inspected?	Yes	Yes	No	No	No
Customarily serviced by trained personnel?	Yes	Yes	Yes	Yes	Yes
Are periodical (seasonal) lubricant changes made?	No	No	No	Yes	No
Low Operating Speed?	Yes	Yes	No	No	No
Relatively Constant Speed?	Yes	Yes	Yes	No	Yes
Practically Constant Normal Load?	No	Yes	Yes	No	Yes
Constant Operating Temperature?	Yes	No	Yes	No	No
Is Gear Lubricant to be used exclusively as such?	Yes	Yes	No	No	No
Is moderate lubricant leakage permissible?	Yes	Yes	Yes	No	No
Excessive Power Consumption either unimportant or not evident?	Yes	Yes	No	Yes	No
Lubricant protected from contamination?	No	No	Yes	Yes	Yes
Will absence or unsuitability of lubrication make itself evident before serious damage occurs?	Yes	Yes	No	No	No
Total Unfavorable Conditions:	3	3	7	9	9

Since both the lubricant and gearing must be conserved and protected, the mechanism is provided with a lubricant-tight case and suitable oil seals. Any tendency towards leakage of lubricant in an automobile axle must be avoided since the rear wheel brakes will be rendered inoperative. Any such lubricating system is dependent to a considerable degree upon the physical properties of the lubricant for its operation. Consequently any factor which will affect the condition of the lubricant, such as temperature change, may impair or even destroy lubrication. For example: If a heavy oil is employed during warm weather or continued operation in order to avoid leakage, and the temperature drops appreciably, such an oil may solidify to the point that channeling or even a complete freeze-up may occur. Fortunately, it is customary and practicable to avoid this effect by changing the type of lubricant in accordance with the seasonal temperature change, as it is not usually possible to obtain one lubricant which will be entirely satisfactory under both conditions.

If a gear assembly is subjected to temperature extremes and no provision is made for changing the lubricant to conform to the temperature, the problem of selecting a suitable product becomes more difficult. The ordinary domestic type washing machine affords an excellent example of such a condition. Structurally these machines are composed of a wide variety of different types of gearing which are combined so as to impart the particular combination of rotating and reciprocating motion to the clothes "beaters," which is dictated by the desires of the individual designer. The gearing is nicely fitted and is entirely enclosed to promote safety and cleanliness. Since the parts are inaccessible and not subject to regular inspection, however, the manufacturer is forced to lubricate them often for the life of the machine. For the sake of operating economy these machines are usually driven by the smallest electric motor which can be depended upon to do the work under normal operating conditions.

During warm weather almost any lubricant will perform well, provided that its viscosity is high enough to prevent leakage, and low enough to give reasonable power consumption. The optimum normal temperature viscosity for any specific design is best determined by experiment but the general tendency is to actually use a higher viscosity than necessary in order to prevent leakage.

The real lubricating problem in such an apparatus becomes apparent only during cold weather. Such a bulky and infrequently used mechanism as a washing machine will be relegated to some out of the way corner when not in use, and frequently the storage place is unfortunately a cold rear porch. When wash day arrives the housewife merely wheels the machine into her kitchen and starts work without further preliminaries, if the machine will start—but sometimes it won't. Most ordinary lubricants which are sufficiently viscous to resist leakage at room temperatures will be-

come solids at outside winter temperatures, and the torque required to "break away" the gearing is then greater than the capacity of the motor.

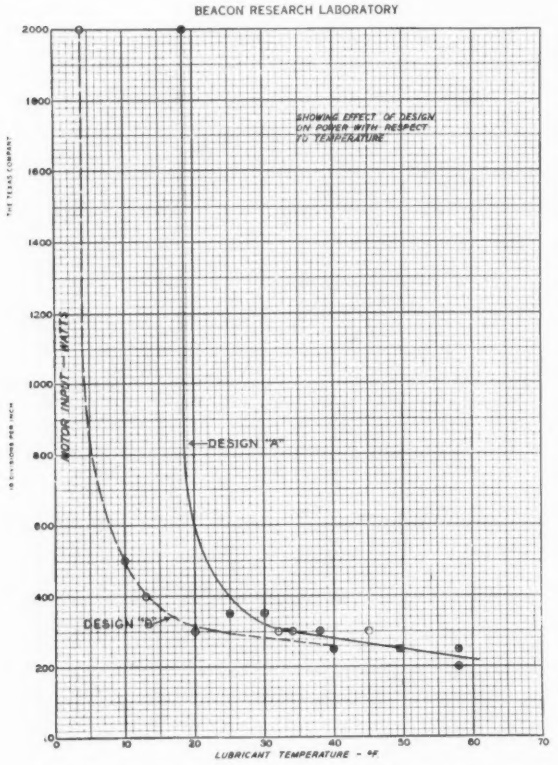

BEACON RESEARCH LABORATORY
SHOWING EFFECT OF DESIGN ON POWER WITH RESPECT TO TEMPERATURE.
MOTOR INPUT — WATTS
DESIGN "A"
DESIGN "B"
LUBRICANT TEMPERATURE - °F
THE TEXAS COMPANY

Fig. 1—Showing the effect of design on power with respect to temperature, as discussed in text.

During the starting period this motor will consume when cold, many times its normal operating current, and if the starting period is prolonged for any reason beyond a few seconds, the motor will either burn out or disrupt the electrical system by blowing fuses. Thus, an improper lubricant may be directly responsible for the breakdown of the entire apparatus. With such a lubricant, even if the apparatus starts successfully, the machine will be unable to do its intended work until the lubricant warms up to room temperature.

A successful lubricant for such an apparatus should be chosen by experiment, because the ordinary laboratory physical tests are dependable only when used as a general guide. This point was illustrated by the results of recent tests in which three types of lubricants were tested at low temperatures in a well known make of washing machine. Although these lubricants were practically interchangeable at ordinary room temperatures, considerable differences in performance were obtained when the temperature was reduced.

The best lubricant could be depended upon to permit the starting of the machine at temperatures which were several degrees lower than the critical temperatures of the others. A parallel test which was run under the same conditions showed that while a decrease in the operating clearance of the gear system had no appreciable effect at normal temperatures, it was very detrimental to starting characteristics in cold weather.

Figure 1 illustrates very effectively the relatively large change in performance which may result from what was considered a minor change in design. In this case the designer, aiming for greater strength and simplicity in production, decreased the clearances to such an extent that the cold starting performance was adversely affected, the net result being an increase from plus 13 degrees Fahr., to plus 25 degrees Fahr., in the minimum starting temperature.

Possibilities in selection of lubricant can be well illustrated by Figure 2 which shows the motor load for various temperatures on a washing machine gear drive when using two lubricants which by the ordinary inspection tests appeared to be practically identical. Yet,

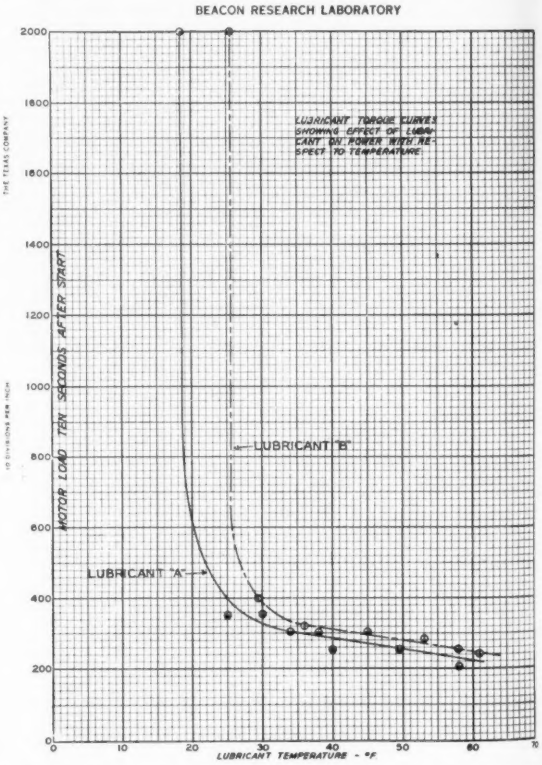

BEACON RESEARCH LABORATORY
LUBRICANT TORQUE CURVES SHOWING EFFECT OF LUBRICANT ON POWER WITH RESPECT TO TEMPERATURE.
MOTOR LOAD TEN SECONDS AFTER START
LUBRICANT "B"
LUBRICANT "A"
LUBRICANT TEMPERATURE - °F
THE TEXAS COMPANY

Fig. 2—Lubricant torque curves showing effect of the lubricant on power with respect to temperature, as discussed in text.

it will be readily seen that selection of the lubricant giving the better low temperature starting performance might easily give all the improvement necessary.

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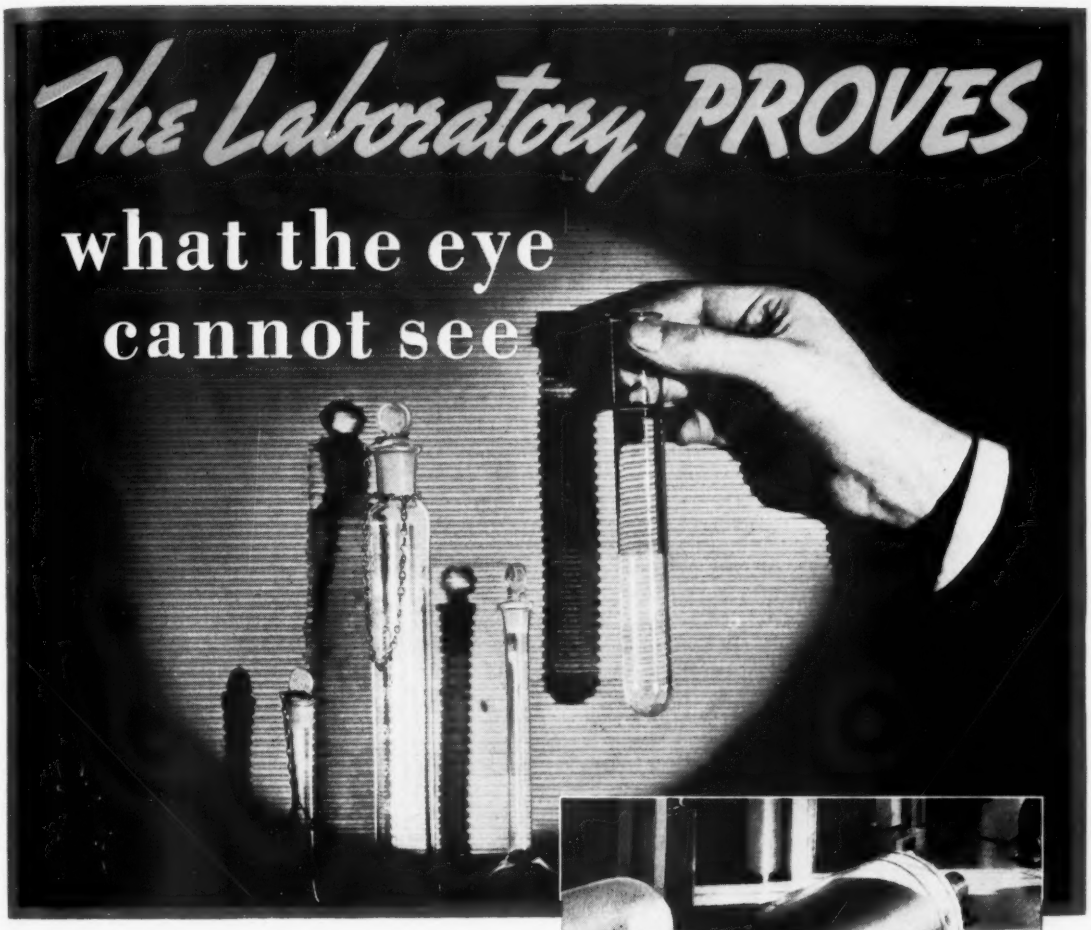

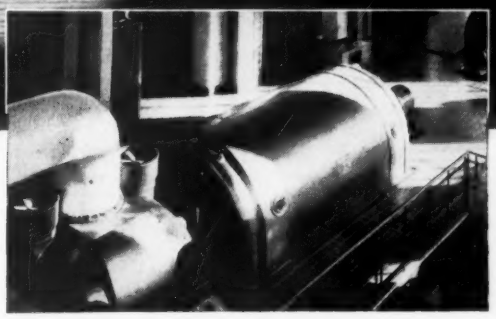

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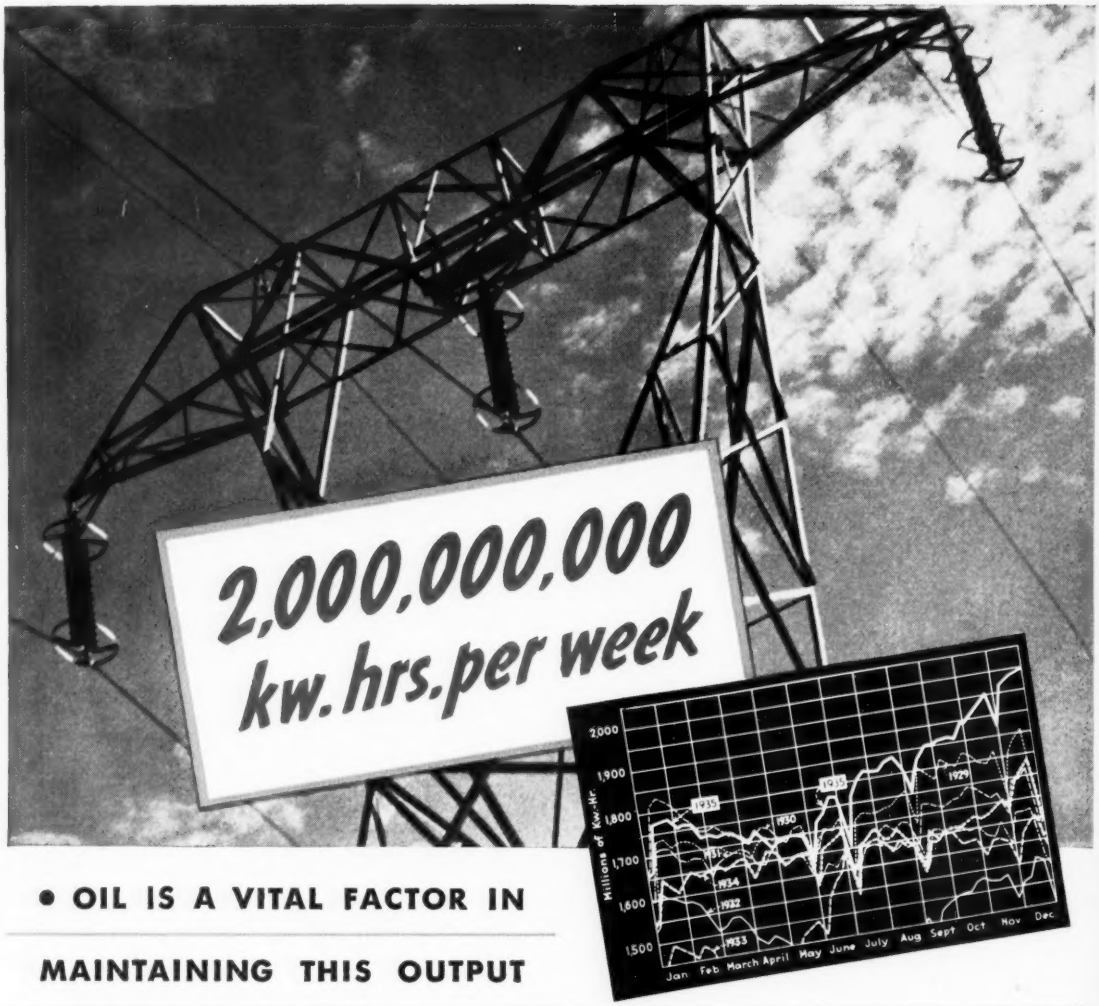

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